

## **GEOMORPHOLOGY IMPORTANCE IN THE LAND EVALUATION AT THE ARGENTINA SUBTROPICAL PLAINS**

Eliseo Popolizio

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**References**

### **Abstract,**

The Argentine subtropical plains are characterized for a very low relief amplitude. They supports continuous drier and floodings periods which are caused by intense rainfalls or large river floods. In order to detect the risk areas, the geomorphology constitute one of the main scientific tools for this study. This discipline is related directly with civil works (dams, bridges, buildings, railroads, etc.) and the spatial organization. The aim of this paper is to describe the main geomorphologic features and the influence of natural risks that overcome either cattle-rising, urbanization, farming, civil work areas. In the paper, we remark the importance of the aerial photographs and the satellite imageries applied to geomorphologic tasks. The importance of these tools is its relation to the thematic mappings. On the other hand, it is analyzed the effect of the paleogeomorphology, altogether associated to oscillating climatic conditions not similar to the actual ones. Finally, the objective is to have in mind the analysis of serious risks originated by the global climatic change and the anthropic action which are actively acting over the large Argentine plains in the last decades.

### **Résumé,**

Les plaines subtropicales Argentinien sont caractérisé pour une relief très basse. Les plaines supporte continu périodes d'inondationnes. Le motif de l'inondationnes sont les pluies et la rivière (fleuve) croissant. Le geomorphologie est une excellent discipline pour l'étude de las surfaces avec

risques geomorphologique. Le geomorphologie donner un coupe de main dans le genie civil et l'organizationne espaciale. Le but de cet article est d'étudier les geoformes de les plaines de l'Argentina subtropical. L'article emphatique l'utilisation de las photographies aéries ainsi l'images satelitales. Finement, c'est analyse l'échange climatique global et leur consequences sur les plaines avec les genie civiles.

### **The main features of the argentinian eastern subtropical plains**

The Argentine northeast region is constituted mainly for a wide area of plains. It embraces the Chaco, Corrientes, Formosa and the south corner of the Misiones Provinces altogether with the north zone of the Santa Fé Province. This area is about 300,000 km<sup>2</sup>. The climatic conditions are typically subtropical. The population is about of four million people.

The rainfalls increase from west to east and the temperature from south to north. Because the unexistence of orographic barriers that could difficult the air masses movements, which generally come from the south or from the north, the increase rain rates are of a constant gradient toward the eastern.

The predominant vegetation is constituted by forests, savannas and mixed prairies. There are large rivers across them: The Paraná, The Uruguay and The Paraguay rivers. The sustainable activities are the agriculture-farming and cattle-rising as well as forestation. On the banks of the Paraná and the Paraguay rivers there are established four large cities called as Posadas, Formosa Corrientes and Resistencia. The last two mentioned cities, Resistencia and Corrientes, have actually about of 400,000 people.

The geomorphologic features have a minimum relief amplitude, about 200 meters. The lowest rates is placed at the south and the maximum heights are placed at the northeastern corner, near the Misiones Province.

Because of this assemblage of heights, the study area generally is outstand-

ingly considered as a very flat surface, slightly plunging to the Paraná-Paraguay rivers. The Paraná-Paraguay rivers constitute the main geomorphologic axis of the subtropical plains region.

The large flat surface is not a simple framework. On the contrary, behind this apparently simple definition regarding relief conditions, there is a great variety of geofoms and some masked or obscured geologic structures not well understanding until now.

They have clear morphometric and genetic differences. Such differences have a great influence in the spatial stablishment and its organization (Popolizio, 1989). At the study region, migration begun with european citizens on the XVI century. This process begun with the foundation of the City of Corrientes on 1588, and spread to a great region.

To recognize the form of the relief and their bahavioring, it is necessary to deforms the vertical scale about ten times with relation to the horizontal scale. This fact was early recognized by Dra Pierina Passotti in many papers related with the 'Llanura Santafesina' situated a little bit to the south of our region.

Using this method, one meter of plain unevenness represent about 100 meters compare with an irregular scarpt mountain area.

By this manner, we can understood how a topographic unevenness of about 10 meters originated by an anthropic embankement of a railroad, may gives place to a floodable area of 10 km of extension. The fact reside in what the regional slopes are of 1/10,000; in other words it is necessary to run a distance of 10 km to obtain an unevenness terrain of only one meter.

At the plains area the topographic maps are few representative and diagnostic because the equidistance between nivel curves which are 2.5 m; so they result in documents wich shows scarce geomorphologic information for precise evaluation.

Only in the northeastern corner of the area (the northeast of the Corrientes Province), the relief is a little abrupt and then morphologic features are more significative given them the possibility to recognize geofoms either in the field or by means of teledetection methods (IGM, 1990).

In spite of the very low terrain unevenness (or relief amplitude) in the geomorphology geofoms, they are determinant in soil formation, vegetation bodies and hidrologic behavioring and so in the spatial occupation and organization of the region.

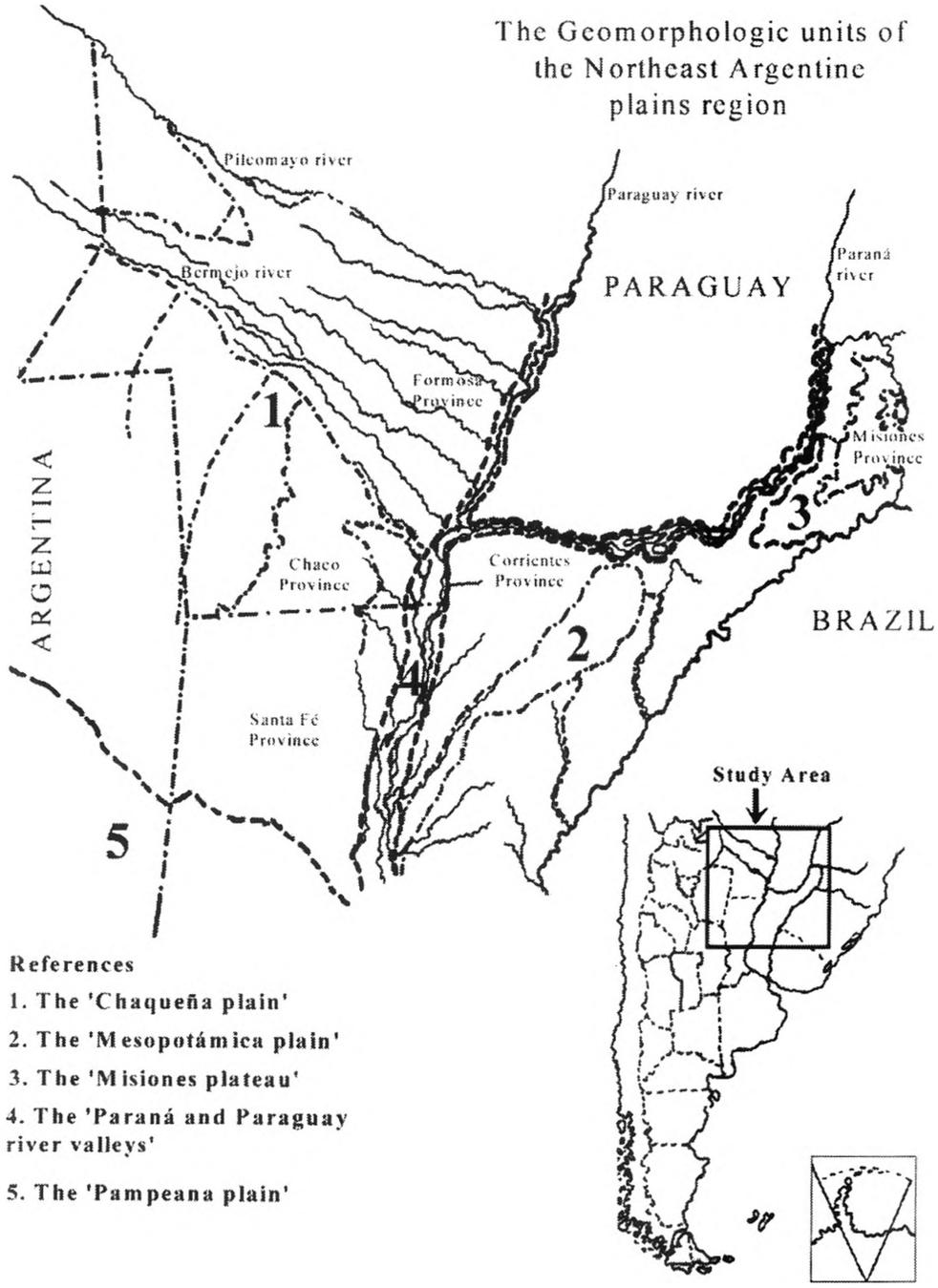
An important topic that should be necessary remark is the fact that many geofoms were originated under very different climatic conditions from the actual ones, at laterly Tertiary ages.

For this reason, many of these are really considered as 'inheritance geofoms'. This situation clearly implies that in the case we could intend to understand genesis conditions will be necessary to study the environment geomorphologic paleoconditions as well as some geologic principles (Popolizio, Fernández and Torra, 1996).

Finally, we must mention that the full area is related to an immense sedimentary relief basin very complex and very old. The history starts at the Paleozoic era. The oldest outcropping rocks are the tholeiithic basaltic lavas from the Mesozoic situated at the extreme eastern of the studied area. In general, all the area is covered by Quaternary sandy-silty-muddy sediments with some outcrops of sedimentary Tertiary beds that outcropping at the abrupt gullies of the Paraná and Paraguay rivers.

### **Main geomorphologic units**

In Figure 1 was classified the main geomorphologic units of the Northeastern Argentine plains. These units were described by the author in earlier studies. (Popolizio, 1975b, 1982, 1989).



**Fig. 1**

In this paper, we have had special consideration to the 'Chaqueña' and the 'Mesopotámica' immense plains areas.

The Chaqueña plain is characterized for a relief that dropped out from the west to the east and embraces three significative

subunits of third order each one. We'll describe their features in summary because they were analyzed in detailed in other papers (Popolizio, Serra and Horta, 1978, 1980).

We start the description from the 'Chaqueña Central Dorsum' which represent

the continuation of the 'Santafesino Occidental Dorsum' (Figure 2).

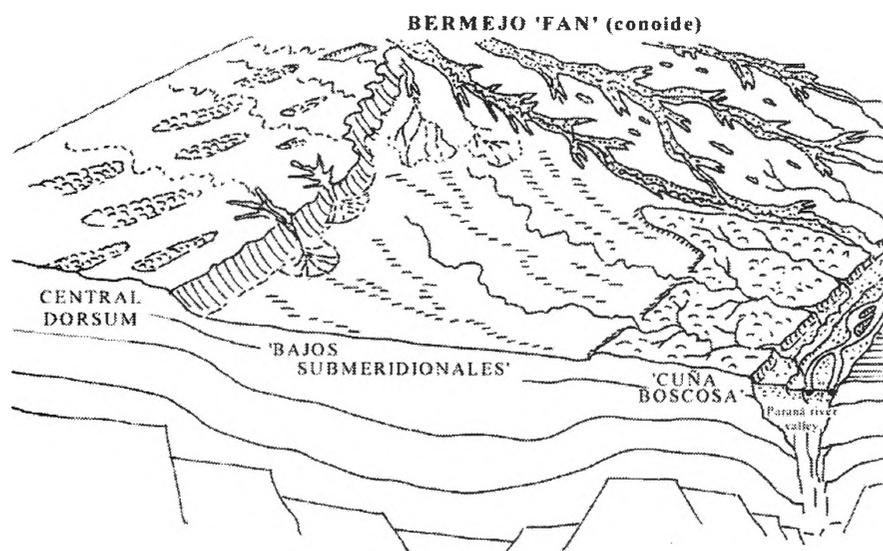


Fig. 2

This unit is related to a basement criptodorsum. Its height average is about of 100 meters over sea level and Saenz Paña represent the main city in the considered zone.

The 'Chaqueña Central Dorsum' is developed in the first order mayor unit called as 'Llanura Occidental del Chaco'. The mayor surface of this area constitute a flat plain in which it isn't possible to observe easily unevenness of terrains.

In spite of, a clear 'dune paleomodel' formed by a chain of hills derived from very fine sandy, silty accumulation deposits which can be recognized for their typical design. They have a height of about one meter and an average width of about one kilometer each ones. Its prevailing orientation correspond to the NE-SW trend.

This morphology elements were covered, at early stages, by a very robust forest. At present days, it is still possible to define many paths of this robust forest but very reduced in extension. The robust forest in general is localized between the substructural plains covered by 'fire savannas' and crossed by fluvial paleovalleys which acted in the form of 'uadis'.

The colmated uadis are characterized for the absence of water currents in surface. This picture shows some isolated basins which in the periods of intense rains can be surpassed or connected by means of laminar flows. In these cases, they drained toward the southeast (Popolizio et al., 1980).

At the east of this subunits extends the 'Llanura Occidental del Chaco' which comprise two subunits as we can see in Figure 2. The first subunit began just in the limit of the 'Chaqueño Central Dorsum', clearly marked by a topographic terrain unevenness scarpment, with a value of about ten meters. They constitute a lowland area located between two topographic dorsums which dropped out to the SE trend.

The unit is a flat plain with some exceptional terrain unevenness which are related to an aeolian paleomodel environment. Also, there are great number of floodable areas which have a trend NW-SE. This give place to the so called 'cañadas' and 'esteros' lagoonal model (a type of water masses of scarce depth and not so extense

like a lake, and so variable in time between drier and more humid conditions like the wet season). At the inner part of these hidric-geofoms there are an incipient fluvial

channel with a scarce capacity of water flowing toward lower terrains.

The environment and the presence of 'palms' correspond to a typical phisognomy called as 'floodable savannas'.

During the periods of great rains the area is almost completely floodable and the mentioned channels only can drained a few volume of water toward the Paraná river valley. For this reason, the exceding of water flows southward, from the Chaco Province to the Santa Fé Province.

This phenomenon gives place to a very wide blanket of water because the unexistence of well defined fluvial courses toward the Paraná river. The geomorphological obstacle for such incipient rivers (channels) is the main geofom called as 'The Dorso Oriental' which come apart the immense lowland areas ('Bajos Submeridionales del Chaco geofom') from the 'Paraná river valley geofom'. This obstacle is constitute by the 'Cuña Boscosa geofom' that makes the waters drops towards south. Then, the physiographic assemblage in the 'Bajos Submeridionales of the Chaco' leds the water to the 'Las Golondrinas system', a little bit more to the south of the study area which finally conected these masses of water with the El Salado river.

The second subunit is other topographic dorsum related to an other criptodorsum called as the 'Dorso Oriental of Chaco and Santa Fé geofom'. This large unit is outstandingly different from the others subunits because they are elsewhere covered by robust forest and a typical dendritic drainage model. Herein the courses discharges to the Paraná river valley. From the point of view of geography, this dorsum is called as 'The Cuña Boscosa'.

Toward the northeast exists the subunit called as the 'Conoides Aluviales of the Bermejo and Pilcomayo rivers' (Popolizio, 1989). These subunits are formed by aluvial paleofans originated by the mentioned rivers (Bermejo and Pilcomayo) under more drier conditions. This climatic cicle gives place to a characterized divergent drainage network model with frequent crevasses ridges which

produced a typical overelevation on the medium altitude plains as we can see in the Figure 3.

Over this overelevated sediments a phisognomy of robust forest was settled (Popolizio, 1989, Popolizio et al., 1978).

Between a couple of overelevated crevasses ridges a fluvial channel was stablished characterize them by a very wide floodable areas. At these areas, the 'esteros' 'cañadas' and the 'savannas with palms' were strongly installed.

In the Figure 2 we can observe a simple skecht of the geomorphological units corresponding to the 'Llanura Chaqueña'.

To the east of the Llanura Chaqueña another unit is present, the 'Llanuras Aluviales of the Paraná and Paraguay river valley'. They present different models developed into its fluvial valleys. So, the Paraguay river valley presents a typical 'meandering design' meanwhile the Paraná river valley has an 'anastomosed model' (an extense braided-type flat-river model).

Both fluvial valleys have a 'meandering trend' in the riverside. A backswamp zone as well as fluvial terraces are present herein like conspicuous geomorphologic fluvial geofoms. However, the Paraná river valley is extended more widely. If we observe all the Paraná river valley extension, the geofom resembles a 'labyrinthine model' as the result of the existence of paralel water-courses yahoo-type, older meanders and floodable and probable-floodable zones.

Between the Paraná and the Uruguay rivers is present the 'Mesopotámica Llanura' which may be divided into three subunits (Figure 1).

The easternmost unit correspond to the Mesozoic rocks, that is to say, the tholeiithic basaltic lavas of the 'Gera Geral Formation' and the beds of the aeolian sandstone giant desert of the 'Botu Catú Formation'. Actually, these formations constitute the 'Serra Geral-Solari Group' following the Argentine geologic nomenclature.

In this area, the relief is more or less abrupt given place to different levels of hills.

They are the results of the climatic changes, oscillations that were recorded from the Upper Tertiary up to day. An exception is present between the Miriñay river and the Aguapey river which represent a floodable area surrounded by more or less elevated zones like the case of the 'Tres Cerros peaks'. They represent older inselbergs of about 190 meters above sea level as is the case of the well known 'Nazareno peak'.

The drainage net is well defined as a characteristic dendritic model. There are, on the other hand, copuliform zones with radioannular drainage model which are possible reflect of older paleotorrent systems originated in more drier conditions. This fact implies that the behaving was largely torrentic in the past (Upper Tertiary-Lower-to-Middle Pleistocene).

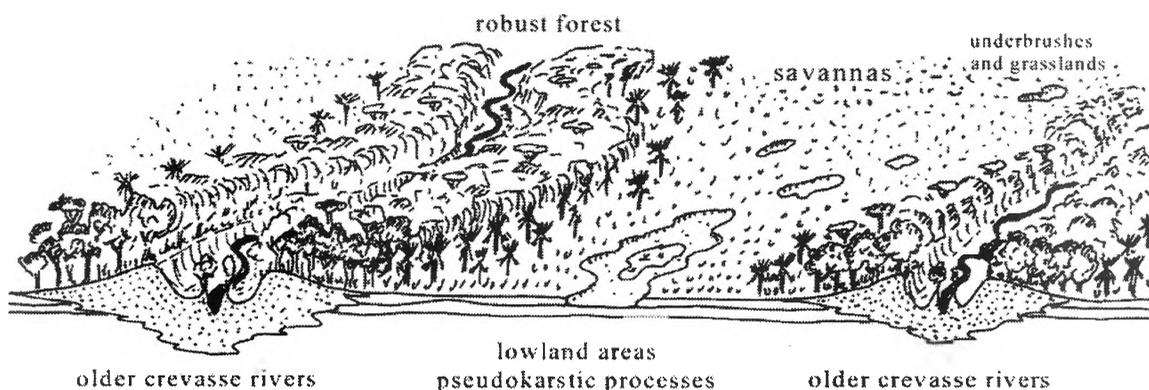


Fig. 2

In this subunit, the underbrush-grassland masses are largely present as well as some scarce paths of robust forest: open or in gallery. The gallery forest is always related to the fluvial courses.

Towards the west there is the 'Depresión Iberana subunit'. This embraces the lakes and lagoonal system of the Iberá geomorphologic-depression, the upper fluvial valley of the Río Corriente and the lowland area of the Sarandí-Barrancas which are an incipient river geform. The north part of this subunit constitute one of the largest 'wetlands' of South America. It is characterized for continuous floodable zones, also lagoonal and, typical 'floating vegetables masses groups', so called in the region as 'embalsados' (Popolizio, 1981). In some cases, these groups constitute true 'floating islands'. The subunit commented herein, is limited at east for a very complex structural lineament which constitute a perispheric depression. There was a time when the Paraná river drained in that depression and

the basaltic rocks (Mesozoic) are now present near the surface. The depths of the tholeiitic basaltic lavas increase westward. The surficial sandy-silty-muddy sediments are Quaternary and created poligenetic geofoms. The occidental limit is formed by sandy-silty hills of about 10 meters in height. However, these hills are difficult to recognize at the field. All the joint constitute a close-basin of about 13,000 km<sup>2</sup> that discharge in the Corriente river. On the other hand, the south sector constitute a great hollowed area with filled fluvial sediments and so giving place to periodically floodable zones which finished in fluvial courses like the Guayquiraró river, a medium tributary of the Paraná river valley.

Finally, the last subunit is constitute for the 'Lomas and Planicies Embutidas of the NW of Corrientes'. It is situated to the west of the 'Depresión Iberana'. It is characterized for a 'suite' of sandy-hills, with a typical design of 'fans' with its NE extreme corner located at the Ituzaingó village. There are lowland plains between the sandy hills assemblage.

This lowland areas are the starting of many little courses of water, sometimes with irregular or lobulated low scarpts, revinement and gullies. The trend of the sandy-hills are 10 meters over the terrain and the 'pseudokarstick' phenomena are one of the more outstandingly little-to-medium geofom present at this zone (Popolizio, 1975a, 1976). A mixed robust forest and underbrush-grassland coberture are present with prevail-

ing arenaceous soils. The sandy hills are related to the Tertiary sediments called as 'Puelchense'. Nowadays, they are called as the 'Ituzaingó Formation' which can be suitable until the Later Tertiary as well as Early Quaternary. The zone have heavy soils and the vegetation is predominantly underbrush or grassland-types with some isolated trees. At the top of the profile are present the Toropí and Yupoí Formations (Figure 4).

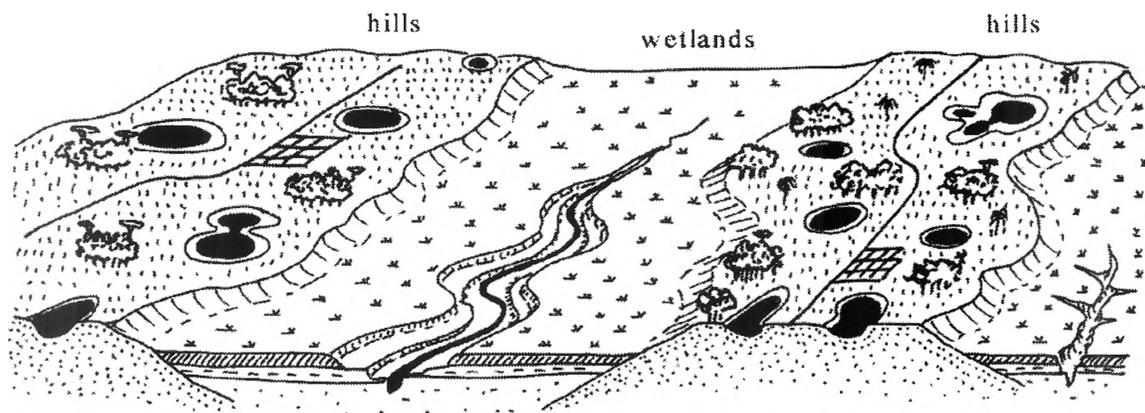


Fig. 4

#### The geomorphologic influence on the geographical spatial and organization related to housing state

The hipothesis of work is that the natural risks determines the land rates as well as the spatial organization.

The natural risks are strongly conditioned for the geomorphology. By this reason, is absolutely necessary a detailed knowledge of the geomorphology as well as the geomorphophysiology in order to know the main risk that can acted on specific zones.

As we can see, the altitude difference in the low relief of the plains is very little as well as the rates of the general surface inclination. Under these conditions, the aerial photography and the satellite images play a great importance to elucidate the relief form. These studies were done at the Centro de Geociencias Aplicadas (UNNE, Argentina), during more than 20 continued years. Technical resources used were stereoscopic vi-

sion with gives the analysts a vertical exaggeration of the low relief geofoms. In this manner is more easy to detect little topographic differences and study masses of vegetation (Popolizio & Canoba, 1986).

The subtropical Argentine plains are characterized for large floodings both pluvial or fluvial in origin. These floodings are mixed with period of very dry seasons. The results of such phenomena is that the anthropic action under these circumstances accelerate erosion processes, specially because the unknowledge of the behavioring of the geomorphologic system and the intensity of the men activities.

The recurrence of such processes acted directly over the spatial organization from the begining of the european housing state in this region of Argentina.

The fluvial routes constituted the natural ways of colonization. This gives place to the birth of various cities settlement; i.e. Resistencia, Corrientes, Formosa and

Posadas cities which are now head of provinces. Other important cities are Goya, Sáenz Peña, Reconquista and so on. However, this urbanization by means of european men didn't were simoulstanely so the 'Gran Chaco region' continue occupy by indians until well later the XIX century.

The large fluvial ways presents significative floodings. When the hydrometric rates reach out the maximum, then the whole river fluvial valley is covered for the water masses. In this situations several cities and surround villages are floods because, as mentioned above, they are completely settled into the fluvial valley.

Formosa, Resistencia and Goya are the cities more affected because they are located in the fluvial terraces. For this reason, they are encourage in the construction of permanent civil works that can control the periodic fluvial floodings. However, many places of the cities are just into the fluvial valley and so they are exposed fully to the flood phenomenon (Popolizio, 2000).

Besides the large fluvial floodings, the region supports the action of pluvial floodings. They are caused because the very low flat land surface and few natural drainage which is high uneficient for flows out the excess of water masses.

This phenomenon occur at the lowland areas situated between the 'Conoides Aluviales del Bermejo and Pylcomayo river (Figure 1). Also, the pluvial floodings affects the immense area called as 'Bajos Submeridionales' in the Chaco Province, the wetland zones ubicated at the Corrientes Province which are outlined by the 'Puelchenses hills' (Figure 4) and the 'Sarandí-Barrancas incipient fluvial course at the south of the 'Depresión del Iberá' (Popolizio, 1981).

Under this circumstances, the urbanization is very scarce, given place to large private properties. The main activities are cattle-rising and, in some sectors the rise cultivation's.

More elevated areas have forest and prairies and customly are dedicated to the agriculture, cattle-rising and forestation ac-

tivities. On the other hand, this terrains were the place for the developed of the main communication ways. Many medium cities and villages were settled just to these ways. So, this cases gives place to a more high density of population and many little piece of grounds were created as well as smallholder phenomena.

On the contrary, toward the east of Corrientes Province, besides the riverside villages near the Uruguay river, appears important population cores settled in the more high places. For this reason, a very important and qualified of cattle-rising activity was stablished and developed. As a result of the geomorphologic features (very hilly), the communication ways appears many times as radial nets and commonly acted as water divisory line.

The paleotorrent model, mentioned above, contribute for the stablishment of little dams which are useful for the explotation of rise field. The irrigation in these cases acted by gravity. This activity is outstandingly increasing nowadays. At the northeastern, the edaphic coberture, a little bit more thickness, gives place to agriculture developing which embraces large field of tea, 'green mate' and soya bean.

The forestation activities are developed at the major part of the Corrientes Province. The species more exploted are pine-trees and eucalyphthus. For this reason, Corrientes Province are nowadays the second largest producer of wood at the Argentina.

In the described scenario adapted to the centered natural conditions excert for the cities and the population cores (villages), was installed a transport communication way unconcordant with the geomorphologic prevailing features. This situation origined many problems in the fluvial natural drainage network because the embankments acted like true 'plains dams'.

In spite of the relative high rates of rainfall, the zone present too a very dry season, which increase towards the west of the considered region. Many times is common dry season for a long periods of time; i.e.

three (common) to seven months (rare). Under the dry season, are very common forest and savannas fires as well as the burning of the harvest.

We can appreciate that the rural population settled at the elevated places (positive arenaceous hills) with minimum flood risk. However, this situation gives place to deforestation mainly changing to the extensive agriculture. In some cases, cattle-rising too was adopted at these zones. The result was the acceleration of soil erosion processes, leaching of soils as well as ravine formations, crevasses and gullies formation.

The global climatic change seems to affects the region from the 60's and their effects seems to be overlapping the anthropic action, in spite of the temperature and rainfalls increase tendency. That effect might be interpreted as a possible change to more "tropical" conditions.

We have been carried out studies on the large fluvial courses, like the Paraná river, seem to indicate an increase in the system oscillation. If this true, the consequences may be greater floodings than the known nowadays. We have a record of floodings that well can indicate that next pluvial and fluvial floodings may be well above in the present century.

As a result of the system oscillation, although seems contradictory, should be possible that more dry seasons will be present in the region, more extensive than the known until now.

In the case that the global climatic change continue in the time and the predictions for this region really occur, the situation led to the producers to change the profile of the custom cultivates. On the other

hand, new illness common at the tropical region could attack our subtropical region because the air masses movements to the south carrying infected vectors.

## Conclusions

The Argentine subtropical plains masked and obscured a great variety of relief geomorphs. They are characterized for a very low difference of terrain unevenness and very low flat surface inclinations.

The use of aerial photographs and satellite images enhance greatly the possibility of reconnaissance of the very low relief geomorphs as well as mapping the main geomorphologic domains.

The geomorphologic features controlled strongly the activities as well as the spatial organization typical in the region. The same is applicable for the natural risks related to drier seasons or floodings scenarios.

The anthropic action installed important changes in the geomorphologic processes which altering drainage model systems and so causing many problems of water erosion.

The global climatic change can act seriously in the region either over the natural risks or over the activities and spatial organization. For this reason, this phenomenon should be get out in consideration for future scenarios that determines the potential use and evaluation of the land. This phenomenon can affect greatly the rates of the lands, the activities as far as the intrinsic spatial organization. ■

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